**BIEN 235 2019W ASSIGNMENT 4**

Due by 10:00 AM on Tuesday, 4/9/2019 (110 points)

***Before answering questions***.

Review the PPT slides for Polymers and Mechanical Properties, your notes from class, and notes from Labs 3 and 4, contact angle measurements and tensile tests, respectively. The text book also has helpful formulas and explanations, if needed. Also, I have included a helpful hints page on the Excel workbook for Homework 4 that is also posted on Moodle.

Download TWO files from Moodle: (1) this document and (2) Homework 4 Excel workbook.

***Assignments are evaluated as individual work***. Write your own answers and make your own graphs/plots.

**CONTACT ANGLE MEASUREMENTS (LAB 3):** Use the spreadsheet on the HW4 Excel workbook.

1. Calculate the mean contact angle and standard deviation for each material in Table 1. Also calculate the range of the angle measurements. Use the calculations for PDMS as an example. Attach the completed table to your homework (or copy it here).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Contact angle measurements from Lab 3:** | | | |  |  |
|  |  |  |  |  |  |
| **Team #** | **PDMS** | **PMMA** | **Hydrogel** | **Parafilm A** | **Parafilm B** |
| 1 | 60 | 150 | 1 | 54 | 38 |
| 2 | 50 | 60 | 10 | 72 | 34 |
| 3 | 112 | 60 | 3 | 70 | 30 |
| 4 | 100 | 45 | 0 | 59 | 23 |
|  |  |  |  |  |  |
| Mean | 81 | 79 | 4 | 64 | 31 |
| Std Dev | 30 | 48 | 5 | 9 | 6 |
| Range | 50 | 15 | 10 | 13 | 11 |

1. (a) Which polymer had the lowest mean contact angle? (b) Is the material hydrophilic or hydrophobic?

Hydrogel, which is hydrophilic

1. (a) Which polymer had the largest range of values (and the largest standard deviation)? (b) Think about the surface of this polymer and then explain why obtaining an accurate contact angle would be a problem.

PMMA

1. Another polymer had a large variability in angle measurements. (a) What is the polymer? (b) What is a difference between these 4 polymer samples that could explain such different contact angle measurements?

PDMS, which is slightly viscous, thus the shape of the surface can vary between the 4 samples.

1. (a) Not including the hydrogel, which polymer had the smallest range of values? (b) Think about the surface and explain why the measurements were all relatively close.

Parafilm B

1. (a) Side "B" of the parafilm was lightly coated with a detergent solution. Detergent molecules are amphiphilic; they have an end that is hydrophobic and an end that is hydrophilic. Based on the difference in the mean contact angle between side A and side B, what end of the detergent molecule is facing toward the parafilm?

Side B is more hydrophilic, so it would seem that the hydrophobic end of the detergent is facing the parafilm.

**TENSILE TESTS (LAB 4):** Use the spreadsheet entitled “Lab 4. Tensile test data” to fill in the table and make a plot for each of the 5 polymers. Also, there is an extra set of test results on the spreadsheet that is for Problem 10. Print the tables and plots and attach them to your homework.

1. TABLES: For the first 5 tables on spreadsheet, calculate the cross-sectional area; there is a cell available on each table. The spreadsheet has data in columns that show the force (N) measured at each change in length (L). There are two empty columns for you to enter your calculated values of the stress (, use units of MPa) and strain (, use the number, not the percentage). The Dec 20th PPT on Mechanical Properties has the formulas that you will need for calculating stress and strain.

PLOTS: Create a plot of stress (vertical axis) versus strain (horizontal axis) for each of these 5 materials. Create a plot that has data markers (circles, squares, or other shape, in any color you like) connected by straight lines. Add a title for each plot with the name of the material and the words “tensile test” (e.g., PTFE tensile test) and label both axes (remember to include the units, when applicable). The numbers on plots *should not* have decimal values (e.g., 0.00, 5.00, 10.00…) unless the major increment is < 1 (e.g., 0.0, 0.5, 1.0, …).

Attach your Excel page(s) with the tables and plots to this assignment. Arrange the data columns and the plots on the page(s) so that they are legible when they are printed. You can arrange your pages in landscape or portrait orientation.

|  |  |  |  |
| --- | --- | --- | --- |
| Low density polyethylene | | | |
| LDPE | | | |
| L0 | 10 | mm |  |
| thickness | 0.1016 | mm |  |
| width | 2.5 | mm |  |
| area | 4.909 | mm2 |  |
| ∆L(mm) | F(N) |  | (MPa) |
| 0 | 0.00 | 0.0 | 0.00 |
| 5 | 2.32 | 0.5 | 0.47 |
| 10 | 2.91 | 1.0 | 0.59 |
| 15 | 2.98 | 1.5 | 0.61 |
| 20 | 3.09 | 2.0 | 0.63 |
| 25 | 3.04 | 2.5 | 0.62 |
| 30 | 3.06 | 3.0 | 0.62 |
| 35 | 3.09 | 3.5 | 0.63 |
| 40 | 3.02 | 4.0 | 0.62 |
| 45 | 3.08 | 4.5 | 0.63 |
| 50 | 3.15 | 5.0 | 0.64 |
| 55 | 3.20 | 5.5 | 0.65 |
| 60 | 3.30 | 6.0 | 0.67 |
| 65 | 3.31 | 6.5 | 0.67 |
| 70 | 3.50 | 7.0 | 0.71 |
| 75 | 3.60 | 7.5 | 0.73 |
| 80 | 3.63 | 8.0 | 0.74 |
| 85 | 3.82 | 8.5 | 0.78 |
| 90 | 3.92 | 9.0 | 0.80 |
| 95 | 4.08 | 9.5 | 0.83 |
| 100 | 4.20 | 10.0 | 0.86 |
| 105 | 4.30 | 10.5 | 0.88 |
| 110 | 4.40 | 11.0 | 0.90 |
| 115 | 4.39 | 11.5 | 0.89 |
| 120 | 4.49 | 12.0 | 0.91 |
| did not |  |  | did not |
| break |  |  | break |

|  |  |  |  |
| --- | --- | --- | --- |
| Ultra high molecular weight PE | | | |
| UHWMPE | | | |
| L0 | 10 | mm |  |
| thickness | 0.1016 | mm |  |
| width | 1.5 | mm |  |
| area | 1.767 | mm2 |  |
| ∆L(mm) | F(N) |  | (MPa) |
| 0 | 0.00 | 0.0 | 0.00 |
| 5 | 2.28 | 0.5 | 1.29 |
| 10 | 4.59 | 1.0 | 2.60 |
| 15 | 5.40 | 1.5 | 3.06 |
| 20 | 6.01 | 2.0 | 3.40 |
| 25 | 6.28 | 2.5 | 3.55 |
| 30 | 6.20 | 3.0 | 3.51 |
| 35 | 6.43 | 3.5 | 3.64 |
| 40 | 6.57 | 4.0 | 3.72 |
| 45 | 6.66 | 4.5 | 3.77 |
| 50 | 6.81 | 5.0 | 3.85 |
| 55 | 7.11 | 5.5 | 4.02 |
| 60 | 7.97 | 6.0 | 4.51 |
| 65 | 8.39 | 6.5 | 4.75 |
| 70 | 8.49 | 7.0 | 4.80 |
| 75 | 8.93 | 7.5 | 5.05 |
| 80 | 9.25 | 8.0 | 5.23 |
| 85 | 9.77 | 8.5 | 5.53 |
| 90 | 10.26 | 9.0 | 5.81 |
| did not |  |  | did not |
| break |  |  | break |

|  |  |  |  |
| --- | --- | --- | --- |
| Polyvinyl chloride | | | |
| PVC | | | |
| L0 | 10 | mm |  |
| thickness | 0.127 | mm |  |
| width | 6 | mm |  |
| area | 28.274 | mm2 |  |
| ∆L(mm) | F(N) |  | (MPa) |
| 0.0 | 0.00 | 0.0 | 0.00 |
| 0.5 | 3.31 | 0.1 | 0.12 |
| 1.0 | 6.10 | 0.1 | 0.22 |
| 1.5 | 8.99 | 0.2 | 0.32 |
| 2.0 | 10.70 | 0.2 | 0.38 |
| 2.5 | 11.80 | 0.3 | 0.42 |
| 3.0 | 12.09 | 0.3 | 0.43 |
| 3.5 | 12.47 | 0.4 | 0.44 |
| 4.0 | 12.88 | 0.4 | 0.46 |
| 4.5 | 12.97 | 0.5 | 0.46 |
| 5.0 | 13.10 | 0.5 | 0.46 |
| 5.5 | 13.22 | 0.6 | 0.47 |
| 6.0 | 13.34 | 0.6 | 0.47 |
| 6.5 | 13.57 | 0.7 | 0.48 |
| 7.0 | 13.72 | 0.7 | 0.49 |
| 7.5 | 13.92 | 0.8 | 0.49 |
| 8.0 | 13.65 | 0.8 | 0.48 |
| 8.5 | 13.74 | 0.9 | 0.49 |
| 9.0 | 13.75 | 0.9 | 0.49 |
| 9.5 | 13.81 | 1.0 | 0.49 |
| 10.0 | 13.88 | 1.0 | 0.49 |
| broke |  |  | broke |

|  |  |  |  |
| --- | --- | --- | --- |
| Nylon | | | |
| Nylon | | | |
| L0 | 10 | mm |  |
| thickness | 0.0254 | mm |  |
| width | 1.5 | mm |  |
| area | 1.767 | mm2 |  |
| ∆L(mm) | F(N) |  | (MPa) |
| 0 | 0.00 | 0.0 | 0.00 |
| 5 | 1.80 | 0.5 | 1.02 |
| 10 | 2.33 | 1.0 | 1.32 |
| 15 | 2.68 | 1.5 | 1.52 |
| 20 | 2.69 | 2.0 | 1.52 |
| 25 | 2.38 | 2.5 | 1.35 |
| 30 | 2.44 | 3.0 | 1.38 |
| 35 | 2.49 | 3.5 | 1.41 |
| 40 | 2.49 | 4.0 | 1.41 |
| 45 | 2.48 | 4.5 | 1.40 |
| 50 | 2.67 | 5.0 | 1.51 |
| 55 | 2.78 | 5.5 | 1.57 |
| 60 | 2.98 | 6.0 | 1.69 |
| 65 | 2.87 | 6.5 | 1.62 |
| 70 | 2.93 | 7.0 | 1.66 |
| 75 | 3.26 | 7.5 | 1.84 |
| 80 | 3.84 | 8.0 | 2.17 |
| 85 | 4.06 | 8.5 | 2.30 |
| 90 | 4.46 | 9.0 | 2.52 |
| 95 | 6.04 | 9.5 | 3.42 |
| broke |  |  | broke |

|  |  |  |  |
| --- | --- | --- | --- |
| Polytetrafluoroethylene | | | |
| PTFE | | | |
| L0 | 10 | mm |  |
| thickness | 0.0508 | mm |  |
| width | 1.0 | mm |  |
| area | 0.785 | mm2 |  |
| ∆L(mm) | F(N) |  | (MPa) |
| 0 | 0.00 | 0.0 | 0.00 |
| 1 | 0.40 | 0.1 | 0.51 |
| 2 | 0.80 | 0.2 | 1.02 |
| 3 | 1.20 | 0.3 | 1.53 |
| 4 | 1.30 | 0.4 | 1.66 |
| 5 | 1.39 | 0.5 | 1.77 |
| 6 | 1.43 | 0.6 | 1.82 |
| 7 | 1.43 | 0.7 | 1.82 |
| 8 | 1.50 | 0.8 | 1.91 |
| 9 | 1.53 | 0.9 | 1.95 |
| 10 | 1.53 | 1.0 | 1.95 |
| 11 | 1.59 | 1.1 | 2.02 |
| 12 | 1.60 | 1.2 | 2.04 |
| 13 | 1.62 | 1.3 | 2.06 |
| 14 | 1.65 | 1.4 | 2.10 |
| 15 | 1.65 | 1.5 | 2.10 |
| 16 | 1.66 | 1.6 | 2.11 |
| 17 | 1.70 | 1.7 | 2.16 |
| 18 | 1.73 | 1.8 | 2.20 |
| 19 | 1.74 | 1.9 | 2.22 |
| 20 | 1.84 | 2.0 | 2.34 |
| broke |  |  | broke |

1. Base your answers to the following questions on your tables and plots of the data.
   1. Considering only the three polymers that broke during increasing strain, which polymer had the highest ultimate tensile strength?

Nylon

* 1. Considering only the three polymers that broke during increasing strain, which polymer had the lowest ultimate tensile strength?

Polyvinyl Chloride

* 1. Elastic behavior (this is the linear part of the curve used to calculate the modulus of elasticity)
     1. Two polymers do not have an elastic region; which polymers are they?
     2. For the 3 polymers with an elastic region, calculate Young’s modulus (elastic modulus). List the material and the modulus (including units) here and show your calculations.
  2. Considering all 5 polymers, which polymer has the highest yield strength (the point at which the polymer deforms)? Which polymers do not have a yield strength?
  3. If you needed the toughest polymer in this group, (a) which one material would you select and (b) what is it about the plot that tells you this?
  4. For 9.e., above, you would therefore not want to use the most brittle (least tough) material. (a) Which one is that and (b) what is it about the plot that tells you this?
  5. List the maximum % elongation to failure for each polymer that broke. For LDPE and UHMWPE, which did not break, use the greater than sign (>) and the last strain measurement. (see Hints page.)

1. At 9:30 pm the *night* before the tensile test lab, Dr. Murray ran preliminary tensile tests for each polymer. All polymers broke before reaching the maximum length of the tensile tester except for LDPE, which was expected. But, when we tested these same polymers in class the next *afternoon*, several of the samples did not break. The strain rate was about the same (i.e., Dr. Murray turned the wheel at about the same speed as all of you). What other condition likely contributed to the material breaking the night?

Room temperature

1. Finish the 6th table by calculating the area and the stress. Then, create a *stress versus time* plot for PTFE on the spreadsheet and label it “LDPE: Stress vs. time at a constant strain” and the axes (with units). Look at the plot and then write the name of the viscoelastic behavior below. ­­­­­­­­­­­­­­­­­

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